COMPENSATING FOR VARIABLE RECORDING CONDITIONS IN FRONTAL FACE AUTHENTICATION ALGORITHMS

Anastasios Tefas† Yann Menguy‡ Constantine Kotropoulos† Ioannis Pitas†

†Department of Informatics
†Aristotle University of Thessaloniki
Box 451, Thessaloniki 540 06, GREECE
e-mail: { tefas,costas,pitas }@zeus.csd.auth.gr

‡MATRA NORTEL COMMUNICATIONS
Rue JP Timbaud-BP 26
78392 Bois d' Arcy Cedex, FRANCE
e-mail: yann.menguy@matranortel.com

ABSTRACT

This paper addresses the problem of compensating for variable real recording conditions such as changes in illumination, scale differences, varying face position, and expression variations. It is well known that the performance of any face authentication/recognition algorithm deteriorates significantly in the presence of the aforementioned variable conditions. The use of simple and powerful pre-processing techniques aiming at compensetating for such variations before the application of any authentication is proposed. It is shown that such an approach overcomes indeed the image variations and guarantees an almost stable performance for the Morphological Dynamic Link Architecture algorithm developed within the European researh project M2VTS.

1. PROPOSED TECHNIQUE FOR FACE NORMALIZATION

1.1. Facial region detection

The problem of compensating for changes in illumination, scale and translation conditions is very crucial for all the verification algorithms that have been proposed in the literature. A new method for face normalization is proposed in order to increase the robustness of the verification algorithm. This method is based on the detection of the facial area in the image and the splitting of the face in two regions (left, right). The images are considered to have uniform background. The proposed algorithm for the detection of the face in the image has the following steps.

Step 1. Discard the uniform background.

Step 2. Find the ellipse that includes the facial area by using ellipse fitting (central moments).

Step 3. Split the facial area in the ellipse in two regions (left, right).

Step 4. Apply K-means clustering in each region in order to segment the skin like area.

Step 5. Redefine the ellipse that corresponds to the skin like area.

By using this method the facial area can be detected and more important the center and the width of the ellipse that corresponds to the width of the face.

1.2. Face Detection by Ellipse fitting

The oval shape of a face can be approximated by an ellipse. Therefore, face detection in an image can be performed by detecting an object with elliptical shape. To do so, first we have to discard the background of the image (which is considered uniform) by using the region growing grassfire algorithm. The image is segmented in two regions (background - face). The next step is to model the face like area by an ellipse. For the region of the face C the best-fit ellipse E is determined on the basis of moments.

An ellipse is defined by its center (x_0, y_0) its orientation θ and the length a and b of its minor and major axes. The center of the ellipse is given by the center of the gravity of the region C. The orientation of the ellipse can be computed by determining the least moment of inertia.

$$\theta = \frac{1}{2}\left(\frac{2\rho_{1,1}}{\rho_{2,0}-\rho_{0,2}}\right) \tag{1}$$

where $\rho_{i,j}$ denotes the central moments of the region C. The parameters a and b can also be computed by evaluating the moments of inertia. The least and the greatest moment of inertia I_{min}, I_{max} of an ellipse with orientation θ are given by:

$$I_{min} = \sum_{(x,y)\in C} \left[(x-x_0)\cos\theta - (y-y_0)\sin\theta\right]^2 \tag{2}$$

This work was carried out within the framework of European ACTS-M2VTS project

$$I_{max} = \sum_{(x,y)\in C} \left[(x-x_0)\sin\theta + (y-y_0)\cos\theta\right]^2 \quad (3)$$

the length a, b of the minor and major axes respectively are given by:

$$a = \left(\frac{4}{\pi}\right)^{\frac{1}{4}} \left[\frac{(I_{max})^3}{I_{min}}\right]^{\frac{1}{8}} \quad (4)$$

$$b = \left(\frac{4}{\pi}\right)^{\frac{1}{4}} \left[\frac{(I_{min})^3}{I_{max}}\right]^{\frac{1}{8}} \quad (5)$$

The objective is to find the ellipse which models better the given region. Thus, an iterative algorithm is presented which aims at the maximization of the measure:

$$M = \sum_{(x,y)\in E\cap C} 1 - \sum_{(x,y)\in E\cap C^c} 1 \quad (6)$$

where C^c denotes the complement of the region C (background). The maximization of the above measure corresponds to the maximization of the correct modeled pixels (i.e. $(x,y) \in E \cap C$) and the minimization of the incorrect modeled pixels (i.e. $(x,y) \in E \cap C^c$). In each step of the algorithm the region C is modified to be the intersection between the ellipse E and the region C of the previous step. The parameters of the ellipse are recomputed and the measure M is evaluated. The procedure is repeated until a maximum for the measure M is reached. The steps of the algorithm are the following:

Step 1. Calculate the parameters of the initial ellipse E_0 and the measure M_0.

Step 2. Find the new region $C_i = C_{i-1} \cap E_{i-1}$.

Step 3. Calculate the parameters of the new ellipse E_i and the measure M_i.

Step 4. if $M_i > M_{i-1}$ go to Step 2
else the best ellipse has been found and it is the ellipse E_{i-1}.

By using this algorithm the ellipse fitting method becomes more robust to noise (clothes, hair, etc.).

The first ellipse that we determine is a coarse approximation of the facial area because in the ellipse are included the hair and maybe a part of the clothes. The next step is to apply a clustering algorithm (separately in each side of the ellipse) in order to approximate the skin like area, which is the important area for the normalization. The segmented area that corresponds to the skin is modeled by an ellipse according to the above described algorithm.

1.3. Lighting normalization

After the detection of the skin like area the face is split in two regions in order to calculate the mean intensity values for the left and the right region of the face separately. For changes in illumination conditions usually the face is darker in the one side and in order to compensate these conditions we assume that the effect of the illumination conditions is uniform in each side of the face. The proposed method aims at the equalization of the mean intensity values in both sides of the face. Let $m_{\text{left}}, m_{\text{right}}$ be the mean intensity values in the left and the right side of the face (best fit ellipse) accordingly. The initial image I is normalized in order to have the same mean intensity value C_m in both sides of the face. The proposed transformation is :

$$I_N(x,y) = C_m \left(\frac{\frac{1}{m_{\text{right}}} - \frac{1}{m_{\text{left}}}}{1 + \mathrm{e}^{\frac{y_0 - y}{\lambda}}} + \frac{1}{m_{\text{left}}} \right) I(x,y) \quad (7)$$

where I_N is the normalized image and λ controls the slope of the sigmoidal function. Let A be the region of the image in which $\frac{1}{1+\mathrm{e}^{\frac{y_0-y}{\lambda}}} \approx 0$ and B be the region of the image in which $\frac{1}{1+\mathrm{e}^{\frac{y_0-y}{\lambda}}} \approx 1$. These regions correspond to the left and the right regions of the face accordingly. Then the following can be proved easily.

$$\mathrm{E}[I_N(x,y)] = \mathrm{E}\left[\frac{C_m}{m_{\text{left}}} I(x,y)\right] = C_m \quad (x,y) \in A \quad (8)$$

$$\mathrm{E}[I_N(x,y)] = \mathrm{E}\left[\frac{C_m}{m_{\text{right}}} I(x,y)\right] = C_m \quad (x,y) \in B \quad (9)$$

The proposed transformation achieves to equalize the mean intensity values of the two sides of the face.

1.4. Translation and scale Normalization

The normalization of the face for varying translation and scale conditions is easy to made if the ellipse that corresponds to the face is determined correctly. Let x_0, y_0 be the center of the ellipse and a, b be the parameters of the axes. The objective is to translate the initial image in order to bring the center of the ellipse in the center of the image. The width of the face is approximated by the length of the axes b. Then the scale normalization is achieved by resizing the image by the factor $\frac{C_s}{b}$ where C_s is the desirable width of the normalized face (Linear interpolation has been used in the experiments).

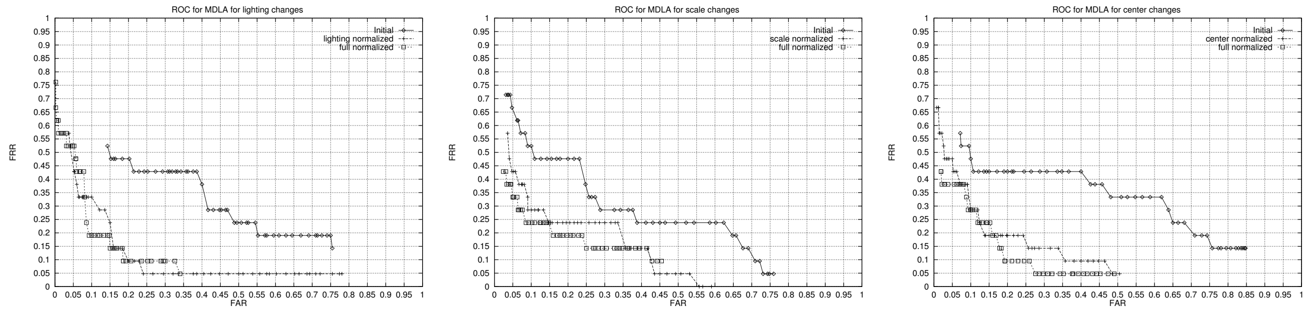

Figure 1: ROC curves for MDLA after with and without normalization

Table 1: EERs achieved in MATRA database (Real conditions) for the proposed normalization method

Test shot	Initial EER (%)	Normalized EER (%)
Optimal	12	9.5
lighting	33	15
scale	28	19
smile	17	13
translation	23	17
general	22	14.7

2. EXPERIMENTAL RESULTS

For the experiments of the method a database created by MATRA Telecommunications has been used. The database includes 21 people in five shots with different conditions. The morphological dynamic link architecture algorithm has been used for the verification. In Figure 2 the ROC curves of the method are plotted for the shots that have differences in illumination, scale and translation conditions. The improvement of the method in terms of EER is shown in Table 1 for all shots of the database. A significant drop of $\tilde{7}\%$ in the general EER of the method is achieved.

3. CONCLUSIONS

The described face normalization method aims at the following:

1. Same mean intensity value in both sides of the face.
2. Translation of the face in the center of the image.
3. Scaling of the face in order to have a constant width.

Experimental results have shown that the proposed normalization method can be used in all cases of real condition images and improves the robustness of the verification method considerably.